Comparison of Mechanical Alternatives for Gully Development Mitigation
Case study: Kerman Province, Southeast of I. R. IRAN

Mehdipour, A.[1] – Soufi, M.[2] – Baniasadi, M.[1] – Alizadeh, M.[1]

[1]Kerman Research Center for Agriculture and Natural Resources, Kerman, Iran.
P.O. Box: 76175-538,Tel. 0341-2110108, Email: azhmahdipour@yahoo.com
[2]Fars Research Center for Agriculture and Natural Resources, P.O.Box 71345-1756,
Tel. 0711-7203010, Email: soufi@farsagres.ir

1. Abstract

Gully erosion causes many problems in Kerman province, southeast of I.R. Iran. It damages rangelands, croplands and infra-structures. A research project began in 2002 to compare the impacts of different alternatives for controlling gully erosion and to introduce the suitable alternative to mitigate gully development in this area. Gully development was monitored in nine representative gullies in the first three years without control and in the second three years with three different alternatives. Average morphometric characteristics of gullies such as top width, depth and length were respectively about 1.1, 1.3, 17.7 meter. View plan and long profile of selected gullies were determined by field surveying. Gully development was measured after rainstorms, when linear headcut extention was measureable, in 3 years. From the 4th year, alternatives such as brush and gabion check dams and water diversion were established in the gullies and their effects on gully development was measured.

The results of this research indicated that at the first monitoring phase gullies developed between 22.5 to 190 cm and their drainage area upstream of headcuts changed between 0.2 and 1.8 m^2, but after establishing the controlling alternatives, gully development was between 5 to 13.5 cm and drainage area changes was between 0.0003 to 0.24 m^2. Therefore all of these three structures was effective and reduced gully development.
Keywords: Gully erosion, mechanical, mitigation, headcut, hedge, gabion, water diversion.

2. Introduction

Soil is one of the most important natural resources in any country. Now soil erosion is a danger for human being. Soil erosion has detrimental on and off site damages. Gully is defined as erosional channel with cross sectional area larger than 929sq.cm (Poesen, 2003). Gully development in Kerman province, south east of I. R. Iran caused many problems for agriculture stakeholders. These gullies should be controlled and prevented to save upland croplands. Different methods to control gully development were not tested in this area. Research on the impact of contour Calliandra-Napier hedges in the Kianjuki catchment area in central Kenya indicated more soil conservation by hedges than in a non-hedged control, on slopes of both 20% and 40%. A seasonal average of 20 mg ha^{-1} and 118 mg ha^{-1} of soil were lost from the conserved plots compared to 157 mg ha^{-1} and 151 mg ha^{-1} for control plots on the 20% and 40% slopes respectively. Maize production on plots with hedges on the 20% slope was on an average 8% less than the control plots; while on the 40% slope, maize yield was 8% higher for plots with hedges compared to the control. The increase on the 40% slope could be attributed to a longer-term trend of reduced run off and soil loss (Angima et al. 1999).

Over a 10-season study period, the combination of Napier grass and Calliandra in contour hedges oriented perpendicular to the hillslope in the maize field was demonstrated to provide a sustainable agroforestry technology combining soil and water conservation with production of high quality fodder. After the initial two hedge establishment seasons, hedges were effective in reducing runoff and soil loss (O' Neill et al., 2001).

On steep hill slopes (24-34^0) in the forest buffer zone of the Blue Mountains of Jamaica, following clearance of secondary forest, the relative impacts on surface runoff, soil erosion and soil properties of three land use treatments were compared: bare (maintained weed-free without cultivation), agriculture (pure maize), and agroforestry (maize inter-cropped with Calliandra contour hedges). The forest provided good protection against surface run off, which was consistently less than 0.2% of rainfall, and against soil erosion losses, which were less than 500 kg ha^{-1} yr^{-1}. Agroforestry was also effective in conserving water, with a 45% reduction in run off compared with agriculture (pure maize), and soil, with erosion reduced by 35%. Agricultural productivity was also higher by 45% in the plots with contour hedgerows and maize grain weights were up by 63% higher per plant (McDonald et al, 1999).

Check dams that made of boulders have been employed for torrent management for high-gradient stream stabilization. A sequence of low check dams made of boulders has been used for bed stabilization. The artificial step –pool grade-control structures in the Maso di Spinelle torrent have been successfully tested by floods events with return periods of about 7– 10 and 20– 25 years(Lenzi, 2002).

The Loess Mesa Ravine Region and the Loess Hill Region, cover 200,000 km^2 of Loess Plateau in China and have serious problems of soil and water erosion. Two primary ways to control the sediment pouring into the Yellow River from this area are planting and engineering measures. The former is not suitable for the

Loess Plateau due to the arid climate and the barren soil, while some of the latter means, such as terrace farmlands, are vulnerable to floods. As a widespread engineering measure, the check-dam system in gullies is one of the most effective ways to conserve soil and water in the Loess Plateau. If layers of at land were formed as the mounds and ridges were cut to fill the valleys, the geographical condition of the Loess Plateau would be greatly improved, and soil and water losses would be thoroughly controlled as well (Xiang-zhou etal, 2004).

3. Study area

The research was done in south-east of I.R.I in Kerman province. Gullies are around croplands in this area with a longitude between 56, 13', 31.6" and 56, 14', 52.4" E and latitude between 28, 49' and 28, 49', 20" N. The average altitude of area is 1811m and according to modified Domartans' method, climate is mild desertic arid. Study area is mainly rangelands and croplands and gullies are formed and distributed around them. Gully development was monitored in nine representative gullies. Selected gullies had U shape cross section and headcut of gullies are mainly cave shape. Average morphometric characteristics of gullies such as top width, depth and length were respectively about 1.3, 0.98; 17.7 meter and average slop above headcut of gullies was 6.35%. View plan and long profile of selected gullies were determined by field surveying. Picture 1 shows a sample of gullies in this area.

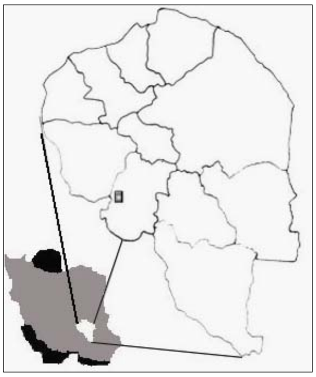

Figure 1 Map of study area

Photo 1 A sample of studied gullies

4.Methods

In order to test the impact of different control measures on gully development a research project with two phases was designed in 2002. In the first phase during three years, gullies were classified based on their location in the landscape, their general and headcut view plans, shape of their cross sections, land use above headcuts and soil material. Nine gullies of one class of so-called criteria were selected and bench marks were installed inside and outside of gullies. Drainage area and slope above their headcuts were measured. Gully development was measured after rainstorms with significant runoff and headcuts recession. In the second phase which was started since 2005, different mechanical structure and alternatives for controlling gully erosion, including brush, gabion and water diversion were established in and above gully headcuts and measuring the length progress and headcut area changes was done regularly after rainstorms. Each alternative was applied in three gullies with relatively similar condition. Some characteristics of gullies are shown in Table.1.

Table 1 Characteristics of selected gullies

Alternative group	Repetition	Length of gully (m)	Headcut drainage area (m^2)	Headcut height (cm)	Slope above headcuts (%)	Land use above headcuts	Average width (m)	Average depth (m)
1put their name	1	18	934.8654	85	4.5	cropland	1.1	1.145
	2	18.8	1004.5981	62.5	4.7	cropland	0.9	0.80
	3	17	2224.2594	88	6	rangeland	1.6	1.25
2	1	18.5	692.195	28	9.4	rangeland	1.1	1.45
	2	17.3	2351.1286	42	7.4	rangeland	1.2	0.80
	3	15.35	1615.8695	23.2	8.7	rangeland	1.3	0.70
3	1	15.5	1493.9235	49	8.8	rangeland	1.8	0.855
	2	15	3452.0294	65	3.2	rangeland	1.4	0.89
	3	24.15	2808.1219	28.5	4.5	rangeland	1.5	0.95

5. Results

The results of this research indicated that headcut retreat was between 22.5 and 190.2 cm in 2.5 years before applying controlling alternatives, and between 5 and 13.5 cm in 2.5 years after their application (table 2). The drainage area above headcuts was changed between 0.13 and 1.77 m^2 before and between 0.0003 and 0.24 m^2 in 2.5 years after applying the alternatives (table. 2). These results revealed the effect of using mechanical structure for gully development mitigation. Sediment was collected behind of brush dams and gabions, and in some of gullies the space between headcut and structure was filled (photo. 2).

Photo 2 Collected sediment behind structures

Comparison of average development in each group before and after using alternatives was done by t-test method. Statistical analysis indicated that there was significant difference ($P<0.05$) between gully developments before and after establishing brush dams and gabions in gullies but there is no significant difference in water diversion. In this group, repetition 2 developed more than other gullies before using alternative because the land use above this gully is cropland and some of irrigating water was entered to the headcut. It also happened in repetition 1 but in repetition 1 a canal above gully limit drainage area and prevents water to enter to gully. Therefore gullies development in this group was so different and there is not significant difference before and after using water diversion although gully development and change of headcut drainage area reduced after water diversion (table.2). The results also revealed that changes of drainage areas above headcuts were significant before and after using alternatives ($P<0.05$) but there was no significant difference between alternatives (using Duncan method). So all of alternatives were effective to control gully development and change drainage area. In groups 2 and 3, gully development and changing of headcut drainage area had significant difference before and after using them. Furthermore these alternatives reduced height of gullies headcut significantly and collected much sediment behind structures.

Table 2 Gully development & changes of drainage area above headcuts before and after establishing alternatives

Group	Alternative	Repetition	Gully development		Changes of drainage area above headcuts		Headcut height (cm)	
			before establishing	after establishing	before establishing	after establishing	before establishing	after establishing
1	Water diversion	1	43.1	6.6	0.504	0.031	85	40.4
		2	190.2	7.3	0.679	0.01	62.5	39.5
		3	43.8	8.5	1.316	0.24	88	66
2	Brush	1	36.2	5	0.203	0.0003	33	11.1
		2	49.6	10	0.316	0.075	42	20
		3	22.5	13.2	0.127	0.003	24.5	2
3	Gabion	1	44.5	13.5	0.504	0.044	65.5	39
		2	66.2	12	0.729	0.034	65	34
		3	39	12.5	0.339	0.024	29.5	10

6. Conclusions

The results of this research indicated that gully development was more than 10 cm each year and it is more than 90 cm in some of them. Mechanical alternatives are effective structures to mitigate gully development in this area. They reduced gully development to 4 cm each year and some of gullies did not develop after using structures. The results indicated that all of alternatives effect on gully development and decrease soil losses. In some parts of this area that irrigation water enter to the gullies using water diversion is effective but in the other gullies brush dams and gabions are more effective. Brush dams are the best structure to mitigate gully development because of their impact for preventing sediment to transfer downstream and availability of material for their construction in the watershed. It is recommended to use brush dams to mitigate gully development.

7. References

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